2.30pm

Perspectives and opportunities for Renewable Energy and National Security

Mike Campbell
Logos Technology

Abstract

Providing sufficient energy, food and water for the world's growing population while at the same time preserving the fragile biosphere are the defining challenges of the 21st century. Such a challenge and the connection and interplay between energy, national and global security is evidenced today by the ongoing tension between the Iran and much of the world due to the its nuclear program, the resulting threat of increasing embargos and the possible interdiction of oil thru the Strait of Hormuz. While the DOD consumes only about 1% of the total US energy use, the Agency is the major "off-take customer for transportation fuel for the US Government (97%) and must heat/cool and provide electrical service to over 300,000 buildings. For bases and military actions outside the United States, logistics associated with delivering fuel is also a major concern. Motivated by both its strategic mission and the practical need for a reliable, domestic source of fuel, the DOD has initiated numerous programs for developing renewable fuels and reducing both its energy intensity and carbon footprint. For example, the stated DOD goal is to have 25% of its energy use supplied by renewable fuels by 2025. The presentation will highlight some recent examples of ongoing programs such as producing jet fuel from cellulosic feedstock and exploring the utility of modular nuclear reactors for forward and remote operating bases.

Biography

Dr. Michael Campbell is the Director of the Energy Division of Logos Technologies headquartered in Arlington, VA. He is responsible for all of the energy activities within Logos which include programs to develop cellulosic feedstocks into ethanol and jet fuel, to close the nuclear fuel cycle in advanced reactors, and in physics of fusion. He has contributed to the development and applications of high power solid-state lasers, nuclear energy (fission and fusion), plasma physics, hydrogen production and energy including biofuels. He is the winner of numerous awards including DOE's E. O. Lawrence Award, the American Nuclear Society's Edward Teller Award, and the American Physical Society's Excellence in Plasma Physics Award, Fusion Power Associate's Leadership Award, and DOE's Excellence in Nuclear Weapons Research. He is a Fellow of the American Physical Society and European Institute of Physics and has 4 patents with several pending. He has authored over 100 publications in major scientific journals. He has presented numerous plenary, invited and review talks at major conferences in the US and abroad and founded the leading international conference on Inertial Fusion and High Energy Density Science-IFSA (Inertial Fusion Science and Applications Conference). He has served on numerous National Academy of Sciences studies and has been a member of the Physics Division Advisory Committee (Los Alamos), Visiting Trustees of Laser Laboratory (University of Rochester), and the Program Committee for the Virtual National Laboratory for the Heavy Ion Fusion Program. He is on the Board of Directors of Evans and Southerland and presently consults for companies involved in fusion, fission, and directed energy lasers.

Campbell received his undergraduate degree at the University of Pennsylvania and advanced degrees at Princeton University and University of Western Sydney where he received the Dr.Sc degree (post Ph.D. degree).

Perspectives and opportunities for Renewable Energy and National Security

Dr. Mike Campbell

USC *Smart Energy Summit*

January 27,2012

Presentation Outline

- ***Motivation***
- BioJet Program
- BioJet Program Status
- Next Steps (commercialization)

U.S. Energy Statistics and Challenges

General U.S. Statistics

- 4.5% of the world's population
- 21% of the world's energy consumption
- 71% domestically supplied
- Petroleum supplies 35% of U.S. energy consumption
- 72% is used in the transportation sector
- Transportation accounts for 27% of U.S. energy demand

U.S. Energy Challenges

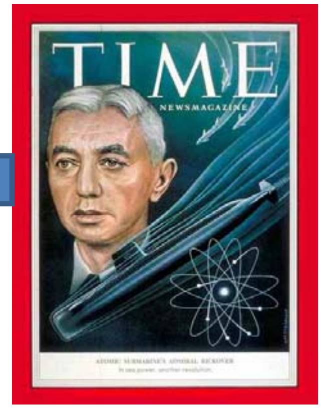
- Consumption of 5.25 billion barrels of oil, 2009
- 3.31 billion barrels imported, 63%
- U.S. domestic oil production
  - Peaking in 1972 at 18.6 barrels/day per well
  - 10.9 barrels/day per well in 2000
- An alternative domestic source and/or technology for producing liquid transportation fuels would increase U.S. energy security

Over the next century there will be a significant transformation of how energy is produced and used but…..

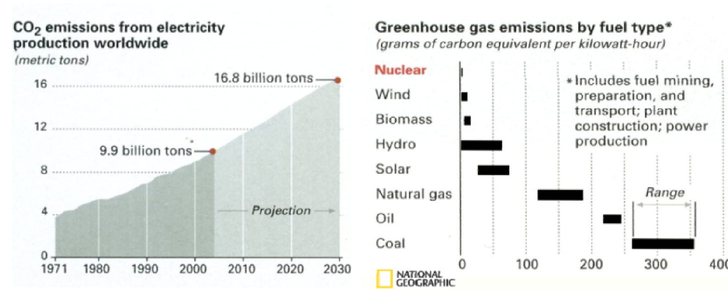
We will still energize planes with Hydrocarbon fuel

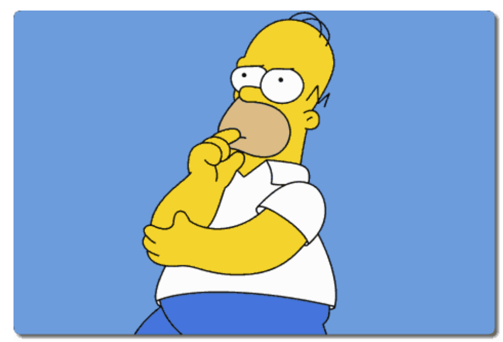
Jet fuel: Airlines use ~16 Bgal of fuel/yr (US is ~35%)

National Security has enabled the development of new Energy Technologies



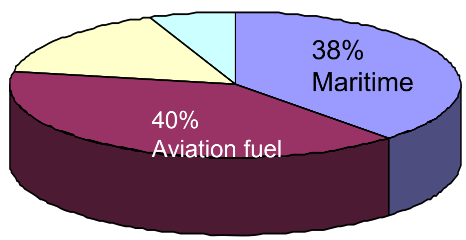
104 Reactors in US produce ~20% of electricity and most C neutral





A strategic thrust of the DOD: 25% Renewable Energy by 2025 (~1Bgal/yr Jet); the Navy is even more aggressive

Increase Alternative Energy Use DON-Wide	By 2020, 50% of total DON energy consumption will come from alternative sources
Increase Alternative Energy Ashore	By 2020, at least 50% of shore-based energy requirements will come from alternative sources; 50% of DON installations will be net-zero
Reduce Non-Tactical Petroleum Use	By 2015, DON will reduce petroleum use in the commercial fleet by 50%
Sail the "Great Green Fleet"	DON will demonstrate a Green Strike Group in local operations by 2012 and sail it by 2016



~0.6% of US Petroleum Use

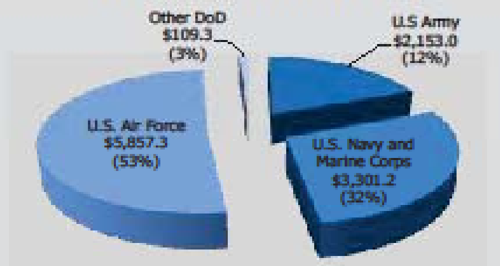
DARPA has established and funded a Biomass to Jet (JP-8) Program in response to DOD renewable Energy Thrust

DARPA Background and Motivation

Department of Defense (DoD) Fuel Use

- The DoD consumes 97% of the government's total liquid transportation fuels – 58% is jet fuel
- In FY09, DoD used:
  - ~2.4B gallons of JP-8
  - ~570M gallons of JP-5
- Jet aircraft require energy-dense hydrocarbon fuel, such as JP-8
- JP-8 is the single fuel for the battlefield

DoD Sales of Petroleum, Natural Gas, and Aerospace Energy ($M)

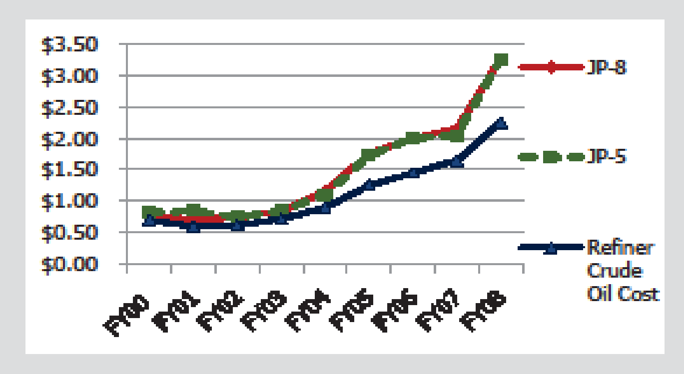


Source: Defense Energy Support Center FY09 Factbook

Commercial Fuel Use

- Total commercial use: 17B gallons Jet-A
- Cost per gallon of Jet-A: $2.10

DoD Fuel Costs vs Crude Oil Price ($/gal)



Concept: DARPA BioFuels Programs

- Crop Oils to JP-8: February 2007 – July 2008
- Broad-based Feedstocks: November 2007 – Current
- Cellulosic Materials and Algal Oils to JP-8: December 2008 – Current

Dependence on unstable and limited foreign petroleum can be greatly reduced by developing multiple, secure, and sustainable pathways to JP-8

Presentation Outline

- Motivation
- ***BioJet Program***
- BioJet Program Status
- Next Steps (commercialization)

The Challenge of Biofuels: "densification" at scale and cost competitive

~8 GJ/ m^2-yr

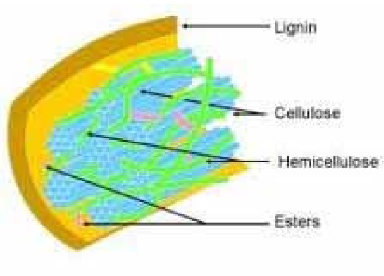
~10-20 dry tons/acre-yr

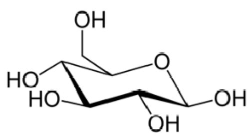
~45 MJ/liter

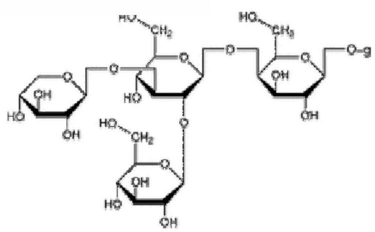
Cost <$3/gal @
< 50 Mgal/yr

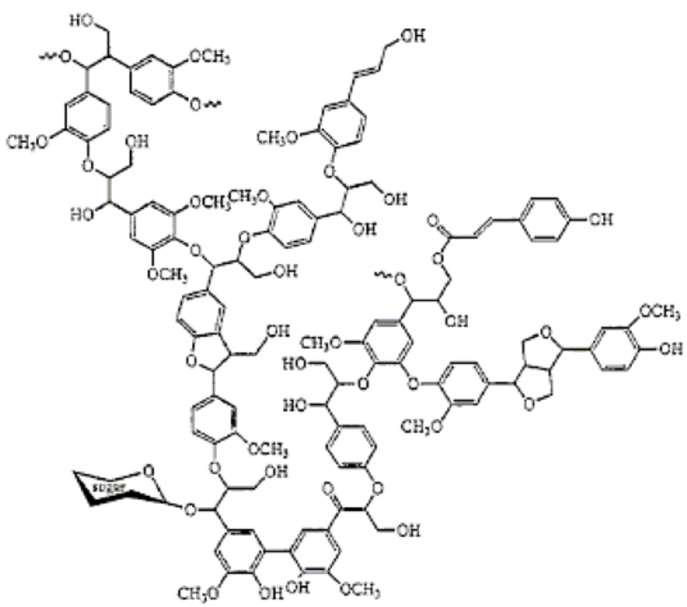
Converting Biomass Into Jet Fuel is difficult!

Biomass

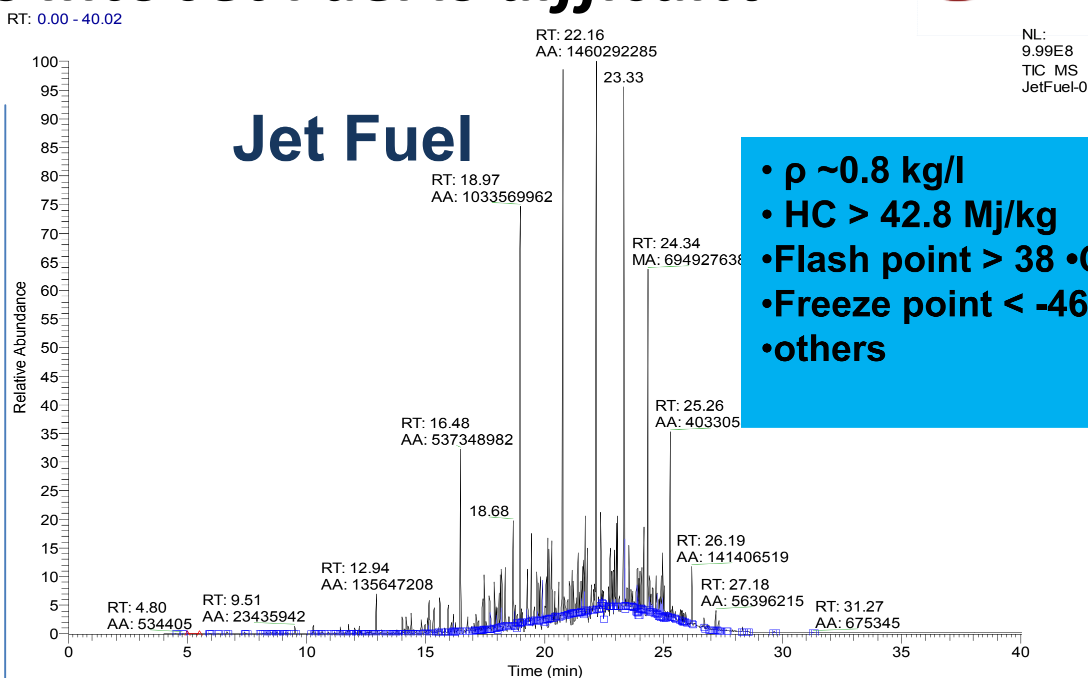






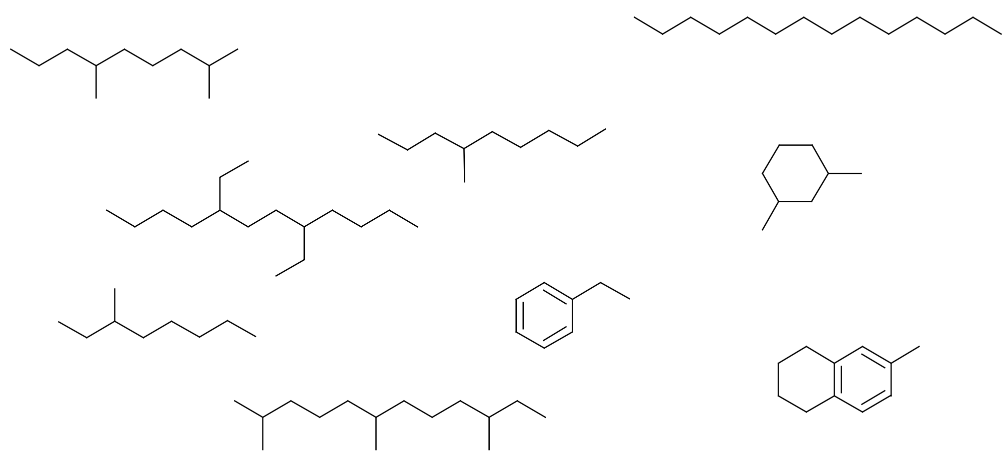


Jet Fuel



- ρ ~0.8 kg/l
- HC > 42.8 Mj/kg
- •Flash point > 38 •C
- •Freeze point < -46 •C
- •others

Carbon Number: 8 9 10 12 14 16



The DARPA BioJet program is focused on the technical /economic challenges of cellulosic feedstock conversion to jet fuel

The Challenge	DARPA BioJet Goals
Economic viability	$3/gal jet fuel cost target – supported by laboratory data of 100 L of JP-8 (Phase 1) and 6000 L (Phase 2)
Efficient conversion of cellulosic material into useable fuel	Laboratory demonstration of conversion efficiency > 30% (Phase 1) and 50% (Phase 2)
Low energy density and transportation of "raw" or "preprocessed" feedstock	Integrated process/cost model (supported by laboratory data) that includes optimized transportation of feedstock and plant sizing
Water, land use, GHG emissions, other environmental constraints	Site specific cost model addresses all issues utilizing the latest environmental modeling

And produce Fuel!

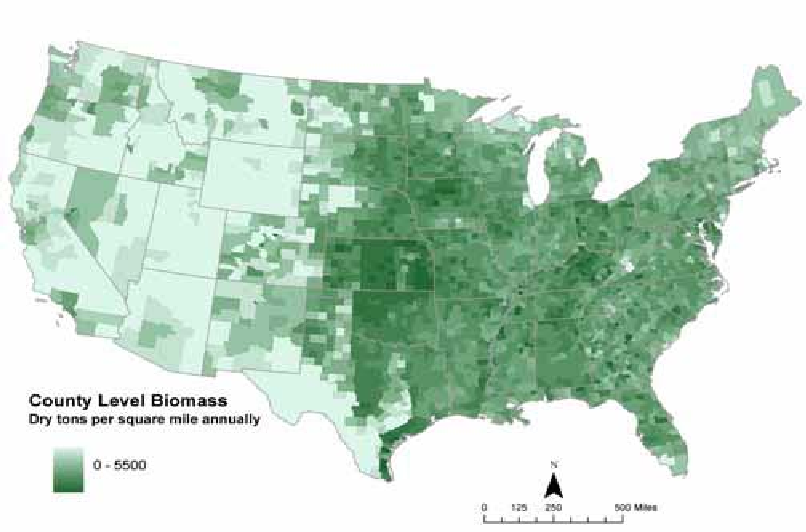
2009			2010				2011				2012
2nd Qtr	3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	3rd Qtr
Fuel Delivered:	2L	2L	2L	2L	100L	--	10 L	10L	10L	10L	6000L

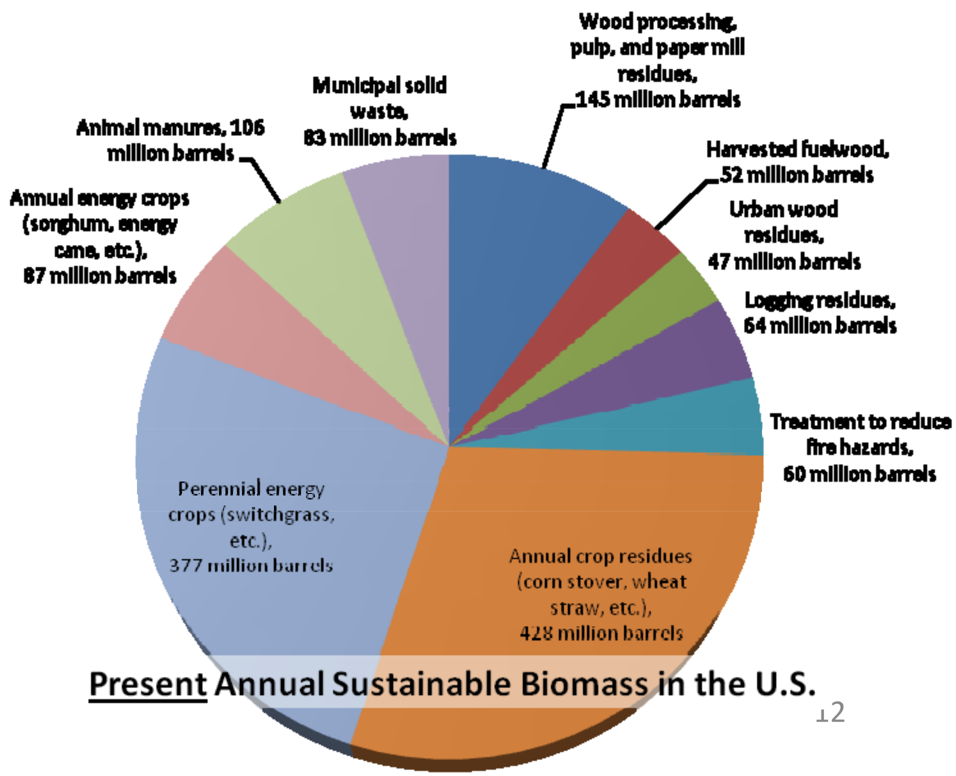
Logos' BioJet Program: JP-8 Fuel Production from Cellulosic Biomass Feedstock

Sustainable Cellulosic Biomass is available_ as an alternative feedstock for transportation fuel

- Enough feedstock for over 1 BILLION Barrels is potentially available today with:
    - **Minimal impact on food production**
    - **Minimal impact on water consumption**
    - **Minimal impact on land use**
    - **Attractive economics**
- BioJet Program has been successful in addressing many of the technical risks including producing >100 L of jet fuel and demonstrating attractive scalable economic performance
- Multiple feedstock with regional variability and a variety of productivities per acre can be utilized:
    - Biodegradable MSW
    - Ag waste
    - Sustainable wood
    - Energy Crops

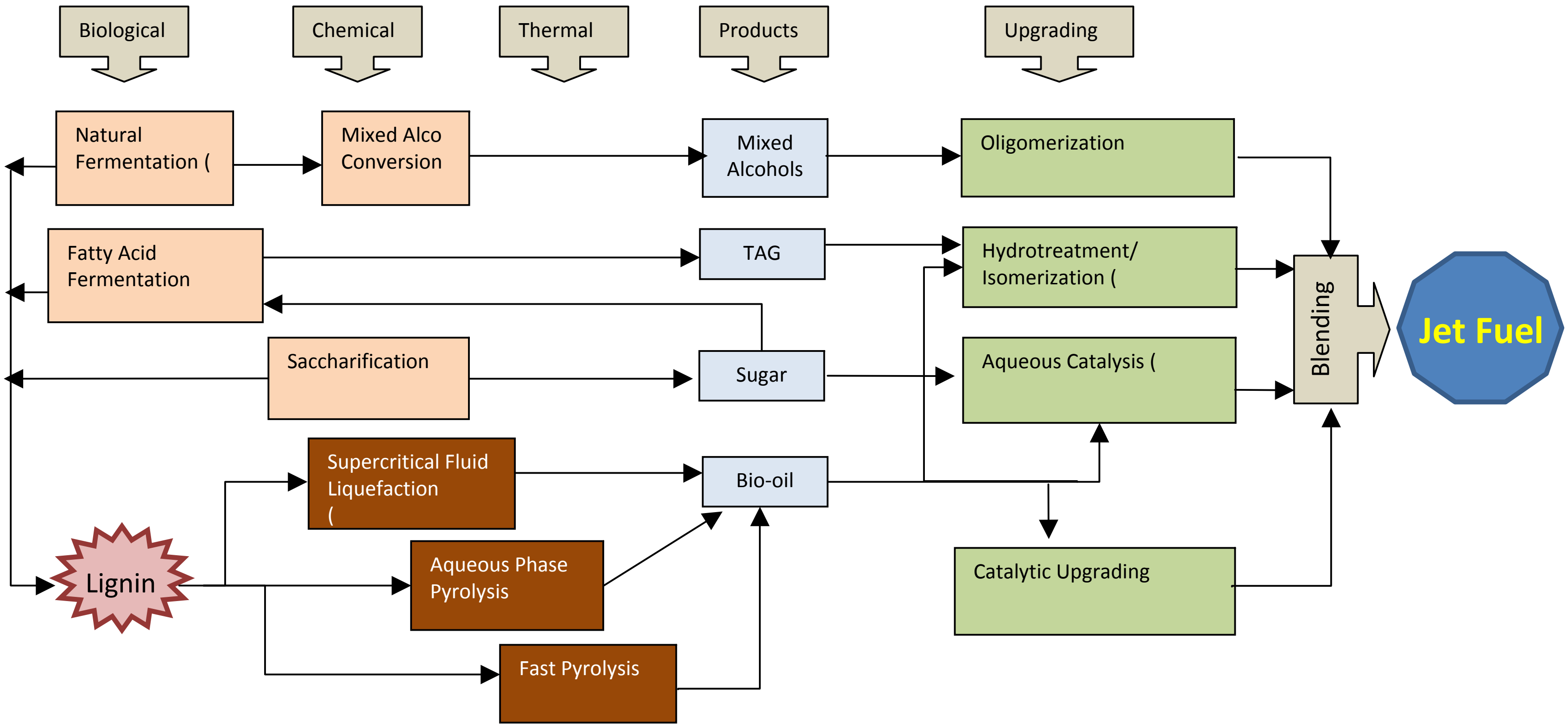
2011 BTS Update





Present Annual Sustainable Biomass in the U.S.

The BioJet Program explored Multiple Paths with many partners to Producing Jet Fuel



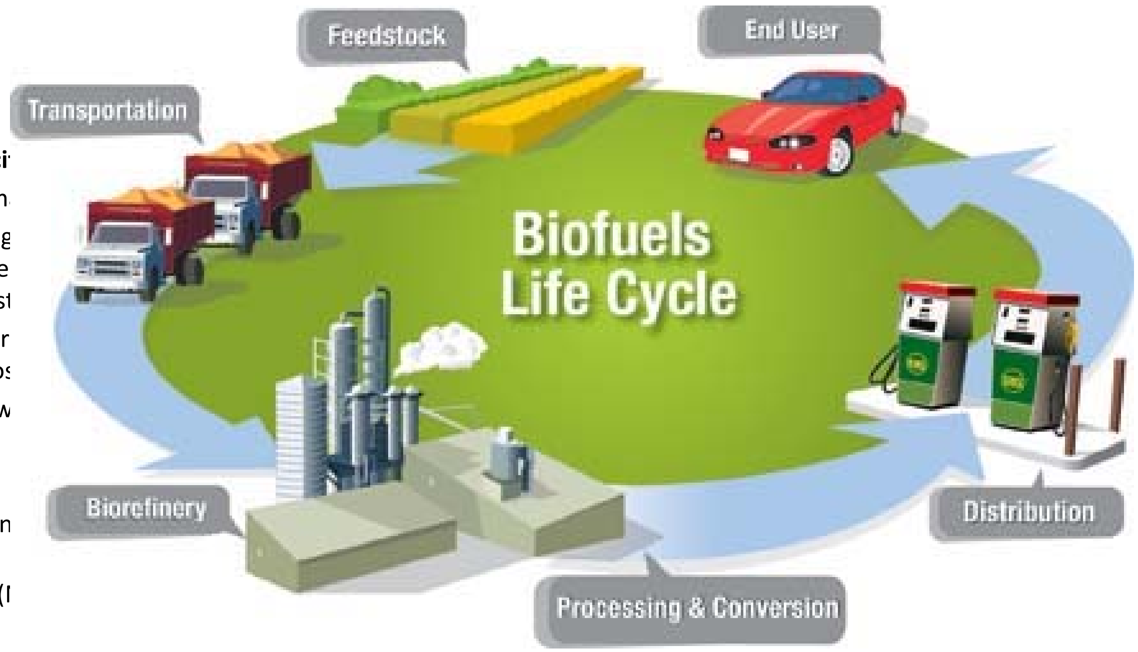
Initial Processing steps for polysaccharides
Initial Processing steps for polysaccharides and/or lignin
Processing steps that produce jet fuel components

While many processes showed promise at bench scale, the requirement to produce JP-8 drove down selection

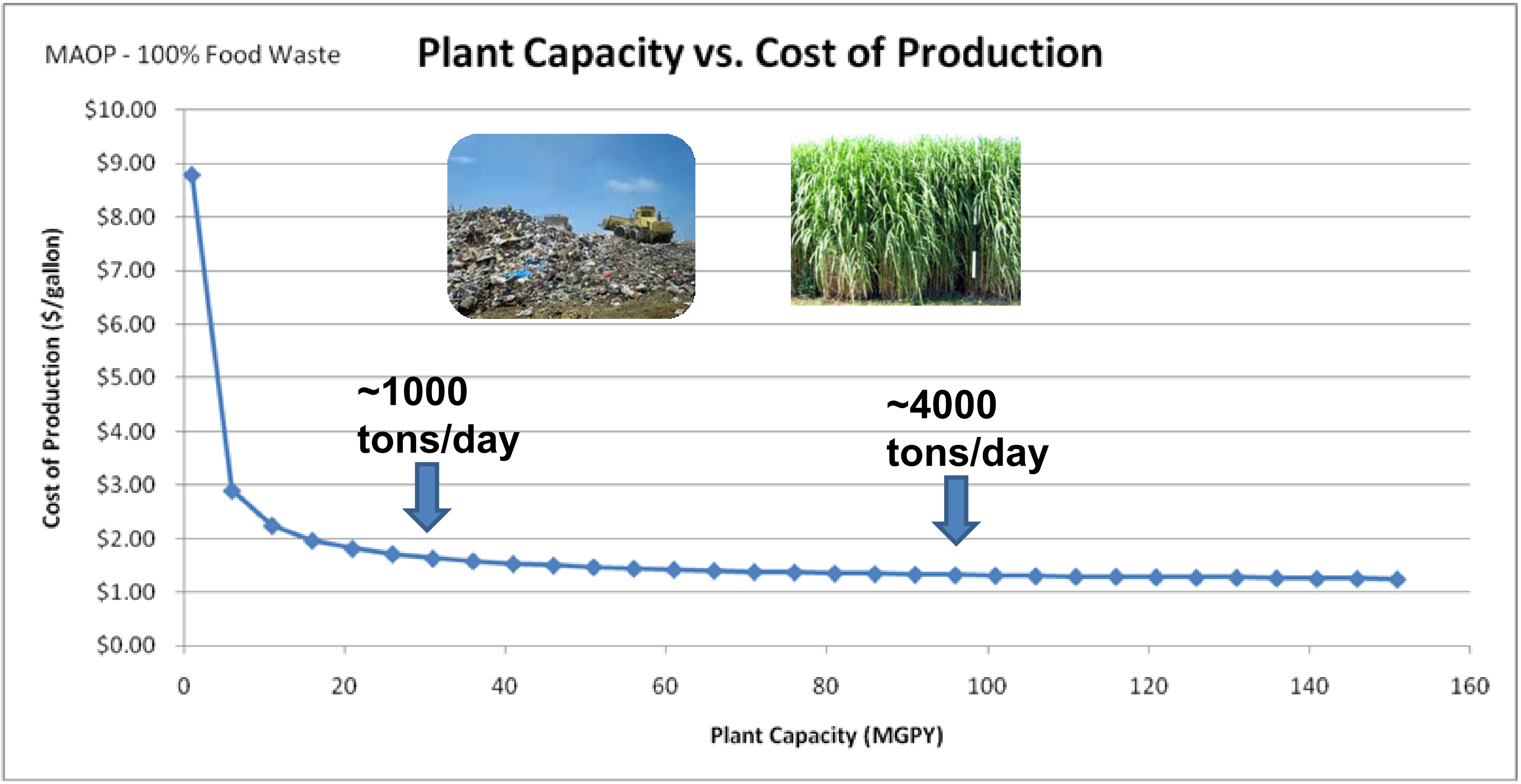
IBET : A life cycle cost analysis tool tailored for analysis of biofuels

Goal: Analyze biofuel pathways stepwise to optimize overall economic performance

- **Features all functionality required to perform an end-to-end techno economic analysis with regional specifici**
  - Summary view of overall system economic perform
  - CAPEX calculations including cost of money, conting equipment, land footprint, installation, startup, site development, working capital and depreciation cost
  - OPEX calculations including revenues and direct var direct overhead, and general and administrative co
  - Ability to analyze multiple biofuel conversion pathw
  - GHG reductions
  - Built in plotting and comparison analysis tools
  - Financial reports including income statement, balan sheet and cash flow statement
  - Internal rate of return (IRR) and net present value (I calculations
  - Step wise implementation of process mass and energy balance relationships
  - Scaling of processes based on exponential rule of economies of scale
  - Ability to inject ramp assumptions (nth plant analysis)



Challenge: Biofuel Refineries @ smallest scale possible for commercial viability



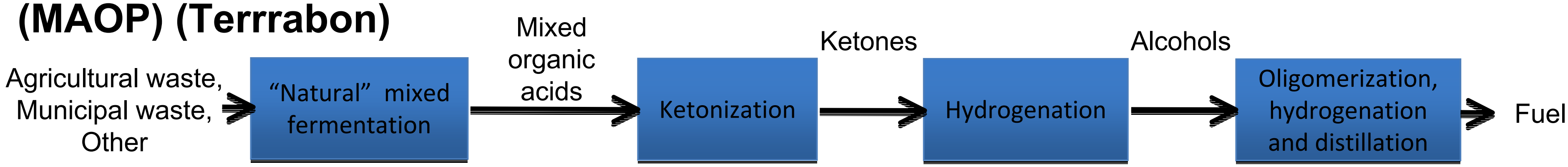
Feedstock Logistics will determine the Biorefinery scale

Presentation Outline

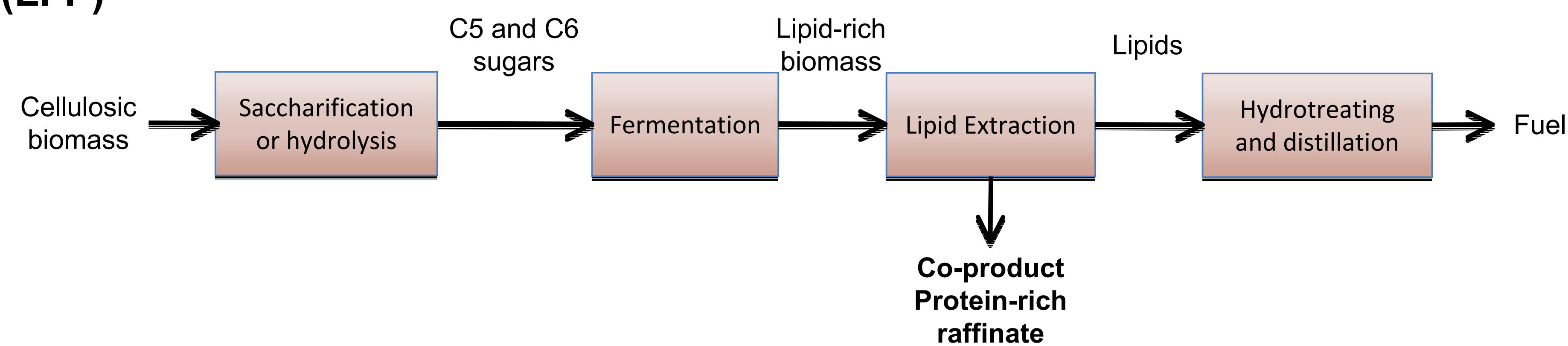
- Motivation
- BioJet Program
- ***BioJet Program Status***
- Next Steps (commercialization)

Two pathways produced fuel with promising economics at scale (>40 Million liters/yr) and were selected for scale-up

Mixed Alcohol (MAOP) (Terrrabon)



Lipid Fermentation (LFP)



Mixed Alcohol Oligomerzation Process

MSW
Biomass
Agricultural Waste

Sorted Waste
- Food
- Paper
- Cardboard

Green waste
Crop residue

Gases
Ash

Pretreatment(1) and "Natural" Mixed Fermentation

Organic Acids

Heat

Ketonization

Ketones

Hydrogen

Hydrogenation

Alcohols

Hydrogen

Oligomerization Hydrogenation Distillation & Blending

Fuel
Gasoline
Jet
Diesel

Feedstock Flexible Process

- Simple Process
- Low CAPEX
- Specification Quality JP-8

Overall Chemical Reaction

$2\ C_5H_7NOPO \rightarrow 2\ CO_2 + C_8H_{14} + \text{Ash}$

Low Water use (~gal_{H_2O}/gal_{fuel}) dependent on feedstock
Fuel is Product
Economics Not dependent on any co-products

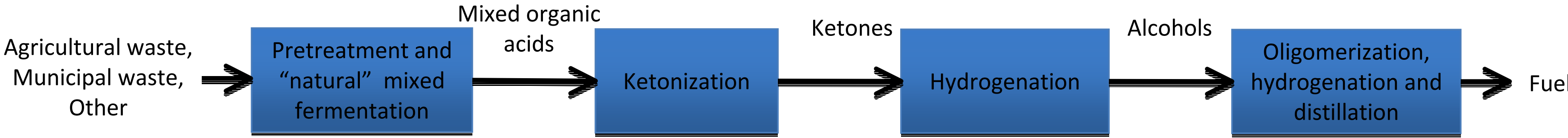
(1) Pretreatment required for feedstock other than Biodegradable MSW

Developed by TAMU!

LOGOS Technologies
TERRABON

Mixed Alcohol Oligomerization Process (MAOP)

Multiple Samples Meeting JP-8 Specification



JP-8 Produced from MAOP

Over 15 Samples Produced

Passed Table 1 Properties

Aromatics Produced

Next Steps

Engine OEM Samples

~300 liters

Full Qualification

~1.1 MM liters

Engaged ASTM / CAAFI

Sample & Feedstock	MIL-DTL-83133G Specification Requirement	19 Waste Paper Chicken Manure	21 Waste Paper Food Waste	22 Food Waste	23 Waste Paper, Food Waste, Chicken Manure	JP-8 Petroleum 4751
Fuel Property						
Aromatics, vol%	**≤ 25**	**16.7**	**17**	**18.2**	**13.8**	**18.8**
Olefins, vol%	≤ 5	0.6	0.6	0.6	0.4	0.8
Heat of Combustion, MJ/Kg	≥42.8	43.1	43.2	43.2	43.3	43.3
Distillation						
IBP (°C)		156	166	167	168	159
10% Recovered (°C)	≤ 205	172	181	186	183	183
20% Recovered (°C)		176	185	191	188	189
50% Recovered (°C)		189	200	206	201	208
90% Recovered (°C)		236	240	241	240	244
EP (°C)	≤ 300	260	259	259	261	265
Residue, % vol	≤ 1.5	1.4	1.5	1.3	1.4	1.3
Loss, % vol	≤ 1.5	0.6	0.4	0.1	0.3	0.8
Properties						
Flash Point (°C)	≥38	52	56	58	58	51
Freeze Point (°C)	**≤ -47**	**-63**	**-61**	**-61**	**-56**	**-50**
API Gravity @ 60 °F	37.0-51.0	46.6	44.6	43.4	45.3	44.4
Density @ 15 °C	**0.775 - 0.840**	**0.794**	**0.804**	**0.809**	**0.800**	**0.804**

Bryan TX Facility will demonstrate MAOP to Jet at scale of ~ton/day

~1 ton/day

6000 liters (JP-8)

Presentation Outline

- Motivation
- BioJet Program
- BioJet Program Status
- ***Next Steps (commercialization)***

The DOD, USDA, DOE have Initiated a potential Title III opportunity to aid in commercializing Biomass to Jet

Georgetown University
March 30th, 2011

"I'm directing the Navy and the Department of Energy and Agriculture to work with the private sector to create advanced biofuels that can power not just fighter jets, but also trucks and commercial airliners." President Obama at Georgetown University, March 2011

RFI placed August 30, 2011

Title III : USG and commercialization

- **Established in Defense Authorization Act (1950)**

- Provides a set of broad economic authorities, found nowhere else in law, to incentivize the creation, expansion or preservation of domestic manufacturing capabilities for technologies, components and materials needed to meet national defense requirements.

- Stimulate private investment in production resources by reducing the risks associated with the capitalization and investments required to establish the needed production capacity.

- **Government-wide statutory authority.**
  - DOD is only federal agency using Title III authorities.

- **Establishes viable industrial capabilities for defense and commercial markets.**

Title III Opportunity would be the Successful Culmination of Biojet

Lab Scale

Fermentors

1 to 20 L

Fuel Produced

~ 1 L

Pilot Scale (BioJet)

Fermentors

20,000 Gallons

Fuel Produced

~ 25 to 1600 Gallons

CAPEX

~$15 MM

Feedstock

~ 1-5 tons/day

Commercial Scale (TitleIII)

Fermentors

1,000,000 Gallons

Fuel Produced

~25 MM Gallon/yr

CAPEX

~ $150-200 MM

Feedstock

~ 1000 tons/day

Commercial MAOP will <u>first exploit</u> MSW as feedstock

Reducing risk of commercialization

LOGOS Technologies

- Worldwide MSW collection infrastructure
  - Locations near urban centers, military bases , airports, refineries
- Constant feedstock deliveries
- Green Technology
  - Extends life of landfills
  - Eliminates associated methane generation
  - Upgrade landfill leachate to clean water and fuel
- Tipping fees versus feedstock costs
- U.S. produces over 250 million tons of MSW a year (700K tons per day)
  - Biodegradable organic waste comprises 20% to 30%
- Supply for over 1.3 billion gallons per year

Potential 25MGal/yr Plant Locations

TERRABON